Affective Haptics in Emotional Communication

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Abstract

In the paper we are proposing a conceptually novel approach to reinforcing (intensifying) own feelings and reproducing (simulating) the emotions felt by the partner during online communication through specially designed system, iFeel_IM!. The core component, Affect Analysis Model, automatically recognizes nine emotions from text. The detected emotion is stimulated by innovative haptic devices integrated into iFeel_IM!. The implemented system can considerably enhance emotionally immersive experience of real-time messaging.

1. Introduction

"*And now here is my secret, a very simple secret; it is only with the heart that one can see rightly, what is essential is invisible to the eye.*"

Antoine de Saint-Exupery

Everything we know about the world entered our minds through the senses of sight, hearing, test, touch, and smell. Our feelings are rich and continuous flow of changing percepts. All our senses play significant role in recognition of emotional states of communication partner. Human emotions can be easily evoked by different cues, and sense of touch is one of the most emotionally charged channels.

Affective Haptics is the emerging area of research which focuses on the design of devices and systems that can elicit, enhance, or influence on emotional state of a human by means of sense of touch. We distinguish four basic haptic (tactile) channels governing our emotions: (1) physiological changes (e.g., heart beat rate, body temperature, etc.), (2) physical stimulation (e.g., tickling), (3) social touch (e.g., hug), (4) emotional haptic design (e.g., shape of device, material, texture).

Driven by the motivation to enhance social interactivity and emotionally immersive experience of real-time messaging, we pioneered in the idea of reinforcing (intensifying) own feelings and reproducing (simulating) the emotions felt by the partner through specially designed system, iFeel_IM!. The philosophy behind the iFeel_IM! (**i**ntelligent system for **Feel**ing enhancement powered by affect sensitive **I**nstant **M**essenger) is "***I feel*** [therefore] ***I am!***". The emotion elicited by physical stimulation might imbue our communication with passion and increase the emotional intimacy, ability to be close, loving, and vulnerable. The interpersonal relationships and the ability to express empathy grow strongly when people become emotionally closer through disclosing thoughts, feelings, and emotions for the sake of understanding.

In this work, we focus on the implementation of an innovative system, which includes haptic devices for generation of physical stimulations aimed at conveying the emotions experienced during online conversations. We attempt to influence on human emotions by physiological changes, physical stimulation, social touch, and emotional design.

2. Architecture of the iFeel_IM! system

In the iFeel_IM! system, great importance is placed on the automatic sensing of emotions conveyed through textual messages in 3D virtual world Second Life, the visualization of the detected emotions by avatars in virtual environment, enhancement of user's affective state, and reproduction of feeling of social touch (e.g., hug) by means of haptic stimulation in a real world. The architecture of the iFeel_IM! is presented in Fig. 1.

In order to communicate through iFeel_IM! system, users have to wear innovative affective haptic devices (HaptiHeart, HaptiHug, HaptiButterfly, HaptiTickler, HaptiTemper, and HaptiShiver) developed by us. As a media for communication, we employ Second Life, which allows users to flexibly create their online identities (avatars) and to play various animations (e.g., facial expressions and gestures) of avatars by typing special abbreviations (e.g., '/laugh' for laughing) in a chat window.

The control of the conversation is implemented through the Second Life object called EmoHeart (invisible in case of 'neutral' state) attached to the avatar's chest. Once attached to the avatar, EmoHeart object (1) listens to each message of its owner, (2) sends it to the web-based interface of the Affect Analysis Model (AAM) [1] located on the server, (3) receives the result (dominant emotion and intensity), and visually

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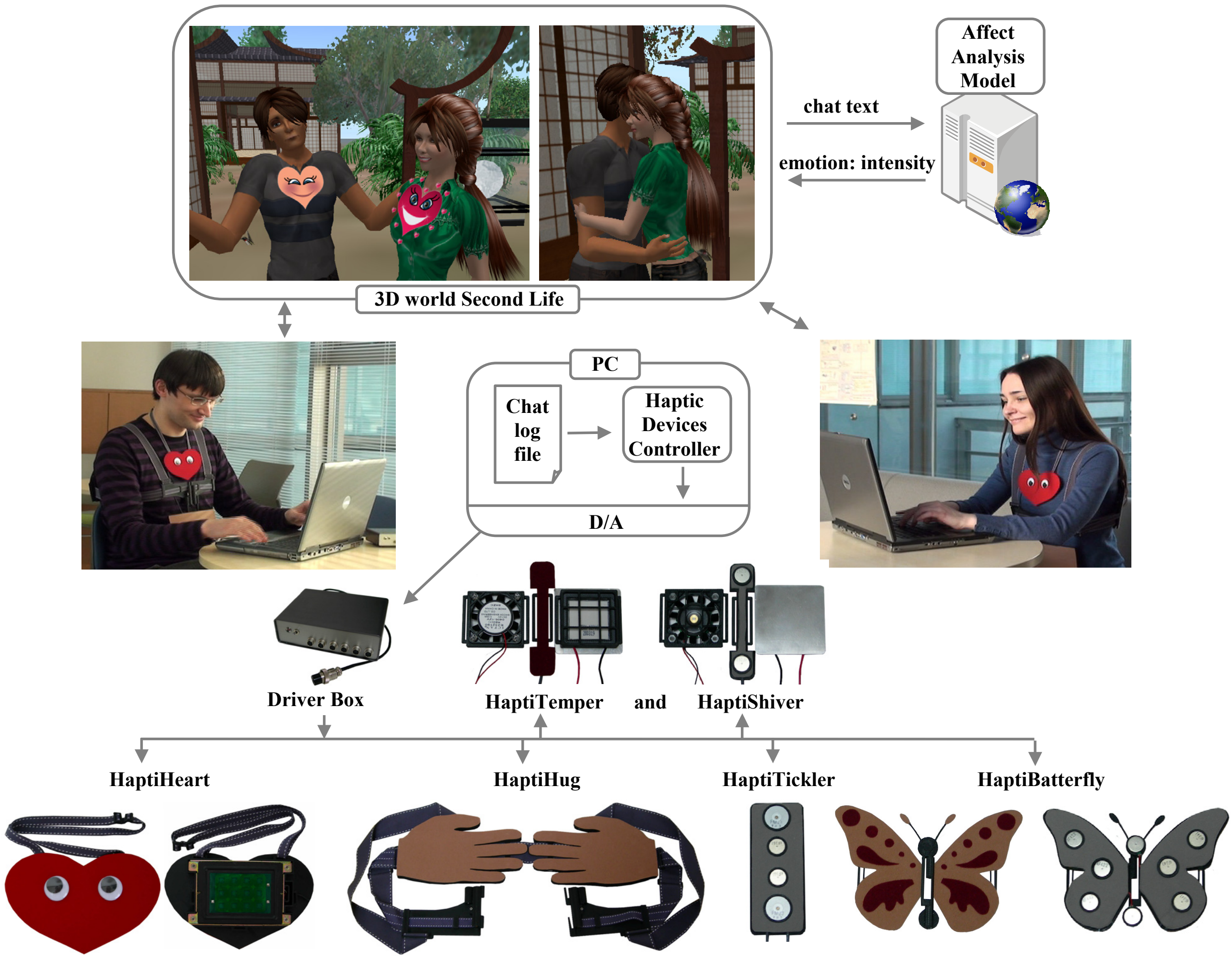

Figure 1: Architecture of iFeel_IM! system.

reflects the sensed affective state through the animation of avatar's facial expression, EmoHeart texture (indicating the type of emotion), and size of the texture (indicating the strength of emotion, namely, 'low', 'middle', or 'high'). If no emotion is detected in the text, the EmoHeart remains invisible and the avatar facial expression remains neutral. The motivation behind using the heart-shaped object as an additional channel for visualization was to represent the communicated emotions in a vivid and expressive way.

In addition to communication with Affect Analysis Model, EmoHeart is responsible for sensing symbolic cues or keywords of 'hug' communicative function conveyed by text, and for visualization (triggering related animation) of 'hugging' in Second Life. The results from the Affect Analysis Model and EmoHeart are stored along with chat messages in a file on local computer of each user. Haptic Devices Controller analyses these data in a real time and generates control signals for Digital/Analog converter (D/A), which then feeds Driver Box for haptic devices with control cues. Based on the transmitted signal, the corresponding haptic device (HaptiHeart, HaptiHug, HaptiButterfly, HaptiTickler, HaptiTemper, and HaptiShiver) worn by user is activated.

3. Recognition of affect from text messages

The Affect Analysis Model senses nine emotions conveyed through text ('anger', 'disgust', 'fear', 'guilt', 'interest', 'joy', 'sadness', 'shame', and 'surprise'). The affect recognition algorithm, which takes into account specific style and evolving language of online conversation, consists of five main stages: (1) symbolic cue analysis; (2) syntactical structure analysis; (3) word-level analysis; (4) phrase-level analysis; and (5) sentence-level analysis. Analyzing each sentence in sequential stages, this method is capable of processing sentences of different complexity, including simple, compound, complex (with complement and relative clauses), and complex-compound sentences. The working flow of the algorithm is presented in Fig. 2.

An empirical evaluation of the AAM algorithm showed promising results regarding its capability to accurately classify affective information in text from an existing corpus of informal online communication. AAM with Connexor Machinese Syntax achieves accuracy in 72.6% on sentences, on which two or three

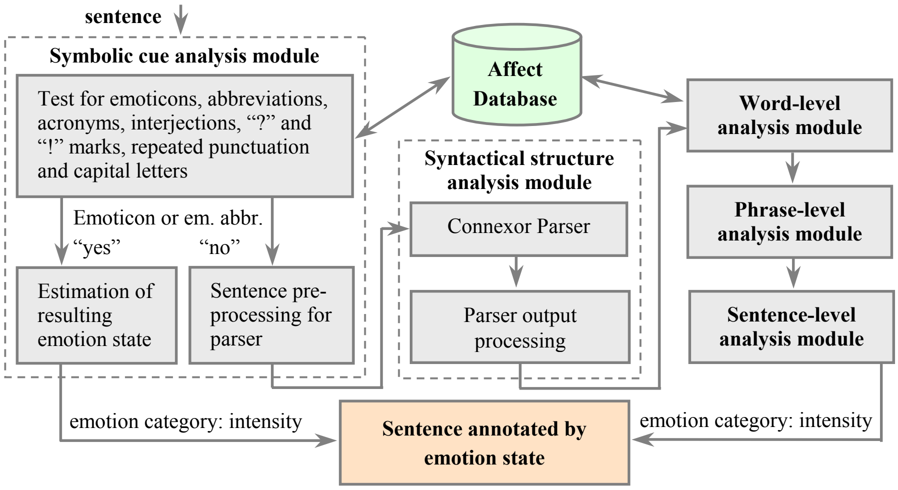

Figure 2: Working flow of the Affect Analysis Model.

human raters completely agreed, and 81.5% on sentences, on which all three human raters completely agreed.

4. Affective haptic devices

According to James-Lange theory [2], the conscious experience of emotion occurs after the cortex receives signals about changes in physiological state. Researchers argued that feelings are preceded by certain physiological changes. Thus, when we see a venomous snake, we feel fear, because our cortex has received signals about our racing heart, knocking knees, etc. Damasio [3] distinguishes primary and secondary emotions. Both involve changes in bodily states, but the secondary emotions are evoked by thoughts. Recent empirical studies support non-cognitive theories of nature of emotions. It was proven that we can easily evoke our emotions by something as simple as changing facial expression (e.g., smile brings on a feeling of happiness) [4]. Moreover, it is believed that some of our emotion responses are mediated by direct pathways from perceptual centers in temporal cortex and the thalamus to the amygdala [5].

In order to support the affective communication, we implemented several novel haptic gadgets embedded in iFeel_IM!. They make up three groups. First group is intended for emotion elicitation implicitly (HaptiHeart, HaptiButterfly, HaptiTemper, and HaptiShiver), second type evokes affect in a direct way (HaptiTickler), and third one uses sense of social touch (HaptiHug) for influencing on the mood and providing some sense of physical co-presence. All these devices produce different senses of touch including kinesthetic and coetaneous channels. Kinesthetic stimulations, which are produced by forces exerted on the body, are sensed by mechanoreceptors in the tendons and muscles. This channel is highly involved in sensing stimulus produced by HaptiHug device. On the other hand, mechanoreceptors in the skin layers are responsible for the perception of cutaneous stimulation. Different types of tactile corpuscles allow us sensing thermal property of the object (HaptiTemper), pressure (HaptiHeart, HaptiHug), vibration frequency (HaptiButterfly, HaptiTickler, and HaptiShiver), and stimuli location (localization of stimulating device enables association with particular physical contact).

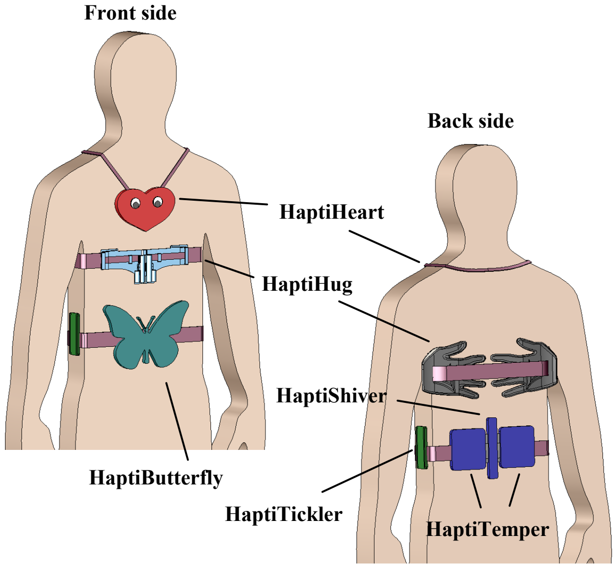

Figure 3: Affective haptic devices worn on a human body.

The affective haptic devices worn on a human body are presented in Fig. 3.

4.1. HaptiHug: realistic hugging over distance

On-line interactions rely on senses of vision and hearing, and there is a substantial need in mediated social touch [6]. Among many forms of physical contact, hug is the most emotionally charged one. It conveys warmth, love, and affiliation. DiSalvo et al. [7] introduced "The Hug" interface. When person desires to communicate hug, he/she can squeeze the pillow, so that such action results in the vibration and temperature changes in the partner's device. However, this interface suffers from inability to resemble natural hug sensation and, hence, to elicit strong affective experience (only slight pressure is generated by vibration actuators); and lacks the visual representation of the partner, which adds ambiguity (hugging in a real life involves both visual and physical experience).

When people are hugging, they generate pressure on the chest area and on the back of each other by the hands, simultaneously. The key feature of the developed HaptiHug is that it physically reproduces the hug pattern similar to that of human-human interaction. The hands for a HaptiHug are sketched from a real human and made from soft material so that hugging partners can realistically feel social presence of each other.

The couple of oppositely rotating motors are incorporated into the holder placed on the user chest area. The Soft Hands, which are aligned horizontally, contact back of the user. Once 'hug' command is received, couple of motors tense the belt, pressing thus Soft Hands and chest part of the HaptiHug in the direction of human body (Fig. 4).

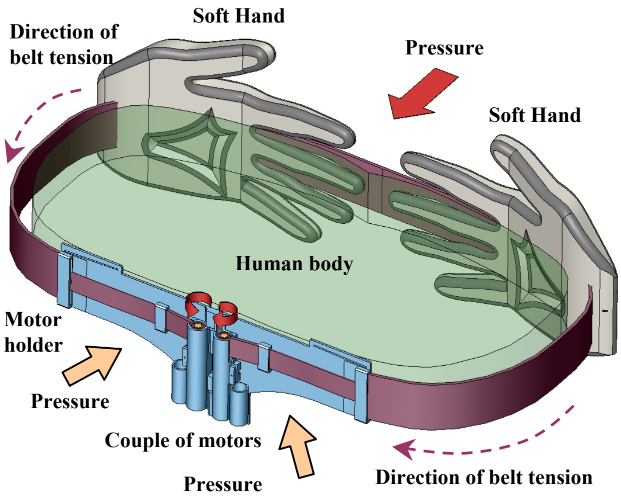

Figure 4: Structure of wearable HaptiHug device.

The duration and intensity of the hug are controlled by the software in accordance with the emoticon or a keyword, detected from text. For the presentation of a plain hug level (e.g., '(>^_^)>', '{}', '<h>'), a big hug level (e.g., '>:D<', '{{}}'), and a great big hug level (e.g., 'gbh', '{{{}}}'), the pressure of 200 N/m^2 with duration of 2 sec, the pressure of 300 N/m^2 with duration of 3 sec, and the pressure of 450 N/m^2 with duration of 4 sec, was applied on the user's back and chest, respectively.

The Soft Hands are made from the compliant rubber-sponge material. The contour profile of a Soft Hand is sketched from the male human and has front-face area of 155.6 cm^2. Two identical pieces of Soft Hand of 5 mm thickness were sandwiched by narrow belt slots and connected by plastic screws. Such structure provides enough flexibility to tightly fit to the human back surface, while being pressed by belt. Moreover, belt can loosely move inside the Soft Hands during tension. The dimensions and structure of Soft Hands are presented in Fig. 5.

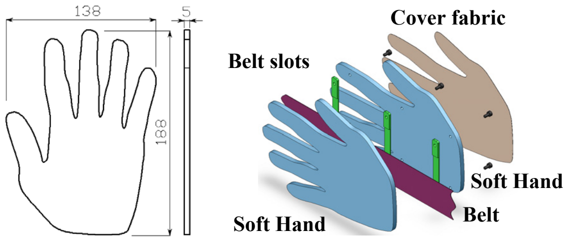

Figure 5: Left: Soft Hand dimensions.
Right: sandwiched structure of Soft Hands.

The significance of our idea to realistically reproduce hugging is in integration of active-haptic device HaptiHug and pseudo-haptic touch simulated by hugging animation (see still image of hugging animation in Fig. 1). Thus, high immersion into the physical contact of partners while hugging is achieved.

4.2. HaptiHeart enhancing our emotions

Each emotion is characterized by a specific pattern of physiological changes. We selected four distinct emotions having strong physical features [8]: 'anger', 'fear', 'sadness', and 'joy'. The precision of AAM in recognition of these emotions is considerably higher ('anger' – 92 %, 'fear' – 91 %, 'joy' – 95 %, 'sadness' – 88 %) than of other emotions.

Of the bodily organs, the heart plays a particularly important role in our emotional experience. The ability of false heart rate feedback to change our emotional state was reported in [9]. The research on interplay between heart rate and emotions revealed that different emotions are associated with distinct patterns of heart rate variations [10].

We developed heart imitator HaptiHeart to produce special heartbeat patterns according to emotion to be conveyed or elicited (sadness is associated with slightly intense heartbeat, anger with quick and violent heartbeat, fear with intense heart rate). We take advantage of the fact that our heart naturally synchronizes with the heart of a person we hold or hug. Thus, the heart rate of a user is influenced by haptic perception of the beat rate of the HaptiHeart. Furthermore, false heart beat feedback can be directly interpreted as a real heart beat, so it can change the emotional perception. The HaptiHeart consists of two modules: flat speaker FPS 0304 and speaker holder. The flat speaker sizes (66.5 x 107 x 8 mm) and rated input power of 10 W allowed us to design powerful and relatively compact HaptiHeart device. It is able to produce realistic heartbeating sensation with high fidelity. The 3D model is presented in Fig. 6.

The pre-recorded sound signal with low frequency generates the pressure on the human chest through vibration of the speaker surface.

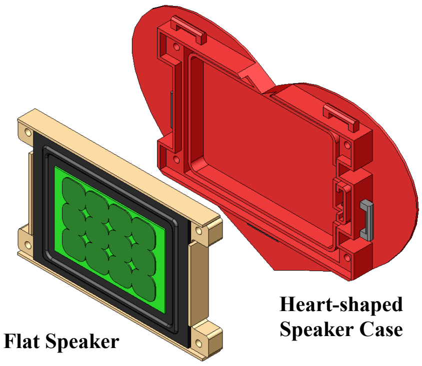

Figure 6: HaptiHeart layout.

4.3. Butterflies in the stomach and shivers on the body's spine

HaptiButterfly is responsible for the evocation of joy emotion (Fig. 7). The idea behind this device is to reproduce effect of "*Butterflies in the stomach*" (fluttery or tickling feeling in the stomach felt by people experiencing love) by means of the arrays of vibration motors attached to the abdomen area of a person.

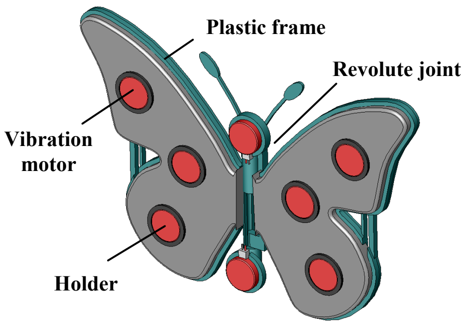

Figure 7: Structure of HaptiButterfly.

We conducted the experiment aimed at investigation of the patterns of vibration motor activation that produce most pleasurable and natural sensations on the abdomen area. Based on the results, we employ 'circular' and 'spiral' vibration patterns in HaptiButterfly.

The temperature symptoms are great indicators of differences between emotions. The empirical studies [8] showed that (1) fear and, to a lesser degree, sadness, are characterized as 'cold' emotions, (2) joy is the only emotion experienced as being 'warm', while (3) anger is 'hot' emotion.

In order to boost fear emotion physically, we designed HaptiShiver interface that sends "*Shivers down/up human body's spine*" by means of a row of vibration motors (HaptiShiver), and "*Chills down/up human body's spine*" through both cold airflow from DC fan and cold side of Peltier element (HaptiTemper). The structure of HaptiShiver/HaptiTemper device is shown in Fig. 8.

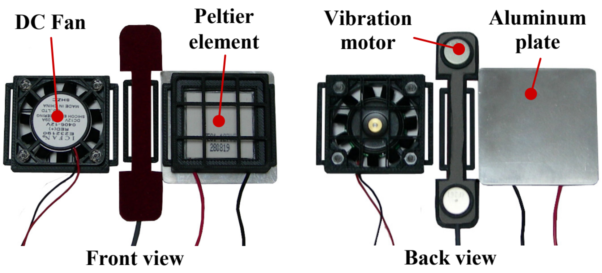

Figure 8: Structure of HaptiShiver/HaptiTemper.

HaptiTemper is also intended for simulation of warmth on the human skin to evoke either pleasant feeling or aggression (it was proved that uncomfortably hot temperatures arouse anger feelings [11]).

4.4. HaptiTickler: device for positive emotions

Two different types of tickling are recognized. The first type is knismesis referring to feather-like (light) type of tickling. It is elicited by a light touch and is generally accompanied by an itching sensation. The second type of tickle called gargalesis is evoked by a heavier touch to particular areas of the body such as armpits or ribs. Such kind of stimuli usually results in laugher and squirming. In contract to knismesis, one cannot produce gargalesis in oneself. Two explanations were suggested to explain the reasons of inability to self-tickling. The scientists supporting interpersonal explanations argue that tickling is fundamentally interpersonal experience and thus requires another person as the source of the touch [12]. On the other side of the debate is a reflex view, suggesting that tickle requires the element of unpredictability or uncontrollability. The experimental results from [13] support the later view and reveal that ticklish laugher evidently does not require that stimulation be attributed to another person. However, the social and emotional factors in ticklishness affect the tickle response greatly.

We developed HaptiTickler with the purpose to evoke positive affect (joy emotion) in a direct way by tickling the ribs of the user. The device includes four vibration motors reproducing stimuli that are similar to human finger movements during rib tickling (Fig. 9).

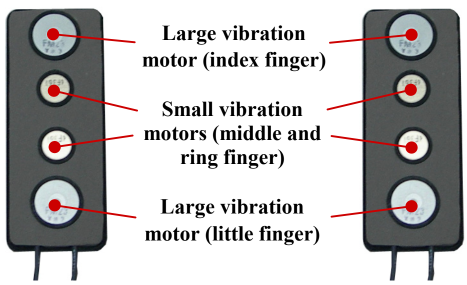

Figure 9: HaptiTickler device.

The uniqueness of our approach is in (1) combination of the unpredictability and uncontrollability of the tickling sensation through random activation of stimuli, (2) high involvement of the social and emotional factors in the process of tickling (positively charged on-line conversation potentiates the tickle response).

4.5. Emotional haptic design

Aesthetically pleasing objects appear to the user to be more effective by virtue of their sensual appeal [14]. The affinity the user feels for an object is resulted from the formation of an emotional connection with the object. Recent findings show that attractive things make people feel good, which in turn makes them think more creative. We propose the concept of Emotional Haptic Design. The core idea is to make user to feel affinity for the device by means of (1) appealing shapes evoking the desire to touch and haptically explore them, (2) usage of material pleasurable to touch, and (3) the pleasure anticipated through wearing.

The designed devices are pleasurable to look at and to touch (colorful velvet material was used to decorate the devices) and have personalized features (in particular, the Soft Hands in HaptiHug can be sketched from the hands of the real communication partner). The essence of emotional, moral, and spiritual aspects of a human being has long been depicted using heart-shaped symbol. The heart-shaped HaptiHeart was designed with primary objective to emotionally connect the user with the device, as heart is mainly associated with love and emotional experience. The HaptiButterfly, its shape, and activated vibration motors induce the association with a real butterfly lightly touching the human body by spreading its wings.

We placed great attention on the comfortable wearing of garment. Such devices as HaptiButterfly, HaptiTickler, and HaptiShiver have the inner sides made from foam-rubber. While contacting the human body, surface shape is self-adjusted to fit particular contour of the human body, and any uncomfortable pressure is therefore avoided. All of the designed devices have flexible and intuitive in use system of bucklers and fasteners to enable user to easily adjust the devices to the body shape.

5. Conclusions

While developing the iFeel_IM! system, we attempted to bridge the gap between mediated and face-to-face communications by enabling and enriching the spectrum of senses such as vision and touch along with cognition and inner personal state. In the paper we described the architecture of the iFeel_IM! and the development of novel haptic devices, such as HaptiHeart, HaptiHug, HaptiTickler, HaptiButterfly, HaptiShiver, and HaptiTemper. These devices were designed with particular emphasis on natural and realistic representation of the physical stimuli, modular expandability, and ergonomic human-friendly design. User can perceive the intensive emotions during online communication, use desirable type of stimuli, comfortably wear and easily detach devices from torso.

The preliminary user study has revealed that developed devices are capable of influencing on our emotional state intensively. Users were captivated by chatting and simultaneously experiencing emotional arousal caused by affective haptic devices. Our primary goal for the future research is to conduct extensive user study on iFeel_IM! system.

We believe that iFeel_IM! will encourage users to get in "touch" with their emotions and to make social contact with other people in on-line communication richer and more enjoyable.

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